mite which would make so much noise should have made a larger hole.

From personal observation, however, I know that dynamite fired on the surface makes much more noise than a more deeply placed charge. At some recent blasting operations I observed the firing of carefully placed charges, and also of some sticks of dynamite laid on the surface. A surface charge which would move less than a cubic foot of material made much more noise than a deeply placed charge which would throw a few cubic yards of material high in the air. The blasting in the strip mine is probably all done with carefully placed charges, and the neighbors did not realize how much more noise a surface charge would make.

The opinion these neighbors expressed was also expressed when an explosion produced a slightly larger crater near Malinta, Ohio, on June 10, 1931.* Press reports stated that windows were broken at a distance of a few miles, and that the concussion was violent at a distance of thirty miles. Persons in the vicinity believed that a quantity of explosive which would make that much noise should have made a larger crater. But oil well experts who examined the Ohio crater said that it was produced by nitroglycerine, about 30 quarts.

To summarize—If the first information received is reasonably accurate and complete, the Linton crater was produced by high explosive. Probably a charge of dynamite on, or very near, the surface was fired.

University of Iowa, April 22, 1936.

NOTE ADDED APRIL 30, 1936.

Since writing the above, we have received a clipping from the *Indianapolis Star,* and a letter from Professor W. A. Cogshall reporting on a further examination of the region of the crater and on the results of excavating to a depth of some six feet. A piece of fuse wire about a foot long was found a few feet away from the crater, and in the digging, some additional wire, which had evidently been through the explosion, was found. The ground two feet below the bottom of the crater had evidently not been disturbed in many years. Professor Cogshall is planning to report more fully on the explosion, and the investigation of the crater.

For the information that the sky was heavily overcast over all the region within a few hundred miles of Linton and throughout the night of March 31-April 1, we are indebted to Mr. J. H. Armington, Senior Meteorologist, of the United States Weather Bureau, Indianapolis, Indiana.

*See *Contributions of the University of Iowa Observatory,* No. 2, page 75; POPULAR ASTRONOMY, **39**, 407.

Contributions from the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD, President, *and* H. H. NININGER, Secretary

The Pasamonte, New Mexico, Meteorite

By H. H. NININGER

The arrival of the Pasamonte, New Mexico, meteorite was marked by what was probably the greatest meteoritic display ever recorded in the western hemisphere for a recovered meteorite. This display has previously been described somewhat at length.[1] The purpose of this paper is to describe the distribution of

[1] *P. A.*, **42**, 291-306, 5 figs., 1934.

the meteorite fragments which have been found, to depict their surface features, and to present some opinions with regard to the meteorites and their behavior during flight. The mineralogical characteristics of the material are being studied by Dr. William F. Foshag of the United States National Museum, Washington, D. C.

I shall mention a few important phenomena connected with the fall, which have been verified since the publication of my previous account. Numerous reliable reports give evidence of the fact that the passage of the meteorite was distinctly heard and felt to distances of more than 100 miles both to the north and to the south of its line of flight. The fireball was described as "the largest ever seen" and by some as "terrifying," from distances as great as 300 miles on either side of its course. In the vicinity of its lower passage near the end of the visible flight, many residents insist that they suffered from a throat irritation throughout the entire day following the fall, and that a peculiar sulphurous odor was noticeable for some hours. These impressions seem the more remarkable in view of the fact that dust storms had been raging in the vicinity for weeks and a considerable storm developed on the day of the fall. Those who report the throat irritation insist that it was like nothing experienced previously or since. Mr. Charles M. Brown of Mt. Dora, New Mexico, who obtained the remarkable photograph of the meteor in flight[2] is responsible for the report that all of the people in his neighborhood suffered from this throat irritation, which was said to have been the subject of much discussion during the day of the fall. Since Mr. Brown is a man who at all times seems to be in complete control of his faculties, one feels inclined to give his report serious consideration. The fact that the meteorite ceased to be incandescent at an elevation of 17 miles, accentuates the difficulty of explaining these phenomena; however, we now know that the meteorite was of such a texture that the several witnessed explosions doubtless set free great quantities of extremely fine dust, the particles of which were all sharp-angled like those of volcanic ash. The enormous cloud which hung in the stratosphere for some time after the meteor's passage probably showered particles of this dust in considerable quantity.

My son and I were at Clovis, New Mexico, on the night of March 23, 1933, and, while the meteor was not visible from that point because of cumulus clouds, we heard about it from numerous witnesses in Melrose, 25 miles to the west of Clovis, a few hours later. We set out at once to gather information from witnesses, and by evening had almost completely encircled the end point. The following day was spent in the gathering of further data. Subsequent trips were made, covering numerous points on all sides of the fall, and after some weeks the course was plotted as described in my previous paper.

Under ordinary circumstances, with its path so definitely plotted, we should have been gathering the stones from this shower very promptly; for we now know that a Mexican sheep-herder on the Pasamonte Ranch was panic-stricken by the falling of stones around his camp and that he later carried into headquarters one of the several small black ones which he picked up. A strange misfortune prevented this happy and prompt fruition of our efforts. When, on the day after the fall, we found that we had to return to Denver without completing the survey, I stopped in Raton, New Mexico, and called upon a patron of the Colorado Museum of Natural History, Mr. Fred Howarth. Mr. Howarth was an official of his bank, and traveling over northeastern New Mexico was a part of his regular activity. He agreed to call at the Pasamonte Ranch and several other ranches

[2] *Loc. cit.*, Fig. 1, p. 291.

in that locality in my stead and ascertain whether there had been any odd-looking stones picked up.

The weeks which followed were busy ones for me. My office was flooded with correspondence concerning the fall. Letters arrived from seven States and it was learned that searching parties had actually gone out to explore various parts of Texas, Kansas, Oklahoma, Colorado, Nebraska, and Arizona—all looking for the meteorite which I knew had landed, if at all, in northeastern New Mexico. As time permitted, I strove to perfect my plotting of the meteor's path. One point worried me: the data as to the height of the end point were not in agreement. The majority indicated a height of 12 to 14 miles. However, a certain few reports which seemed to come from the most reliable sources, indicated a height of 17 to 18 miles. Several of these were accompanied by photographs of the persistent cloud. These naturally carried considerable weight.

When a message came announcing the sudden death of Mr. Howarth from a heart attack, I realized that there was yet work to be done in the Pasamonte region. However, I had received a letter from him some days earlier stating that he had inquired throughout Union and Harding Counties without result. All of the literature on meteor paths and meteorite falls made it apparent that the meteorite should be looked for, not under the end point of the visible meteor, but beyond, at a point somewhat short of that at which its projected path encountered the soil. All of my previous experiences had borne out the same idea; consequently I felt that the matter could await my convenience, especially since Pasamonte was several miles back from the point where the meteor vanished. This meteor had traveled at a very low angle, about $8\frac{1}{2}°$ with the horizontal, as attested by observers and as recorded on photographs of its train. Its projected path touched the earth far to the west. A search was attempted in the vicinity of Wagon Mound, 30 miles beyond the vanishing point. To allow for those estimates of greater altitude, a similar effort was made at points still farther on, but all to no avail.

As time went on I checked and rechecked all data, interviewed more witnesses, and kept stimulating the search for stones. I could not give up the search for what was evidently one of the greatest meteoritic falls in history. Except for the disagreement on the matter of height, my data appeared perfectly satisfactory. If only that one point could be cleared up, the search could be restricted to a much smaller area. At last I met Mr. E. H. Wolff of Pueblo, Colorado, who was in a position to settle the question of altitude. From his bedroom window Mr. Wolff had watched the fireball as it "appeared to roll along the comb of the roof" of a neighboring school building. Here it was possible to make an accurate measurement of the angle of elevation from the pillow where rested the observer's head while he watched the moving meteor and saw its extinction. This observation finally settled the matter of height as approximately 17 miles where the meteor had vanished.

It now seemed that an intensified effort of search was justified in the westernmost area previously designated, but the searcher for meteorites has many surprises in store for him. I chanced to be passing through Clayton, New Mexico, on December 23, 1933, and decided to detour via Pasamonte in order to check personally this region in which it seemed there should have fallen some small fragments from a body which had produced such an enormous cloud as this meteor had left in its wake. I regarded this cloud as due to meteoritic dust, and if that idea were correct, then there should have been scattered some sizable chunks of the meteorite which had disintegrated to form the cloud. To my surprise, Mr.

Howarth had not been seen at the Pasamonte Ranch at all; nor had any other investigator been there. Still more surprising was the information that one of the herdsmen had brought to the ranch house just such a fragment as I was seeking. The stone had been very friable and the various men of the force had each "whittled at it with his knife" until it had all been destroyed. Fortunately other herdsmen were known to have picked up some of the same kind of stones, and, although most of these had been mashed to pieces, there were a few still preserved so that we were able to verify the truth of the report. Mr. O. P. Gard, a farmer six miles to the west, had preserved very carefully a stone from the day it had been found. In his wife's diary the date of its finding had been recorded as April 3, 1933, ten days after the fall occurred. This stone was in a perfect state of preservation and is shown in the photograph (Fig. 1).

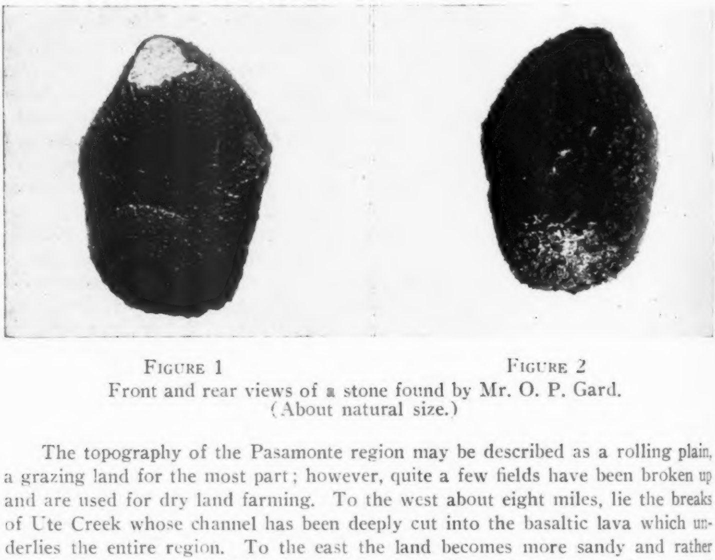

FIGURE 1 FIGURE 2
Front and rear views of a stone found by Mr. O. P. Gard.
(About natural size.)

The topography of the Pasamonte region may be described as a rolling plain, a grazing land for the most part; however, quite a few fields have been broken up and are used for dry land farming. To the west about eight miles, lie the breaks of Ute Creek whose channel has been deeply cut into the basaltic lava which underlies the entire region. To the east the land becomes more sandy and rather hilly. On the south of Pasamonte, about five miles, the country is broken and rugged. The region is very sparsely settled, rendering a thorough search quite impossible; however, we at once canvassed the entire neighborhood, exhibited specimens, and urged the preservation of any meteorites which might be found. For these we offered attractive prices.

CHARACTERISTICS OF THE PASAMONTE STONES

This campaign soon began to bear fruit, and, in the two years following, resulted in the recovery of some 70 small stones aggregating a weight of about four pounds.[3] The largest stone found weighed less than 300 grams. These meteorites are of the stony (aërolitic) variety classified as *Howardites*. The crust is very

[3] In addition, several stones were gathered by an amateur collector who learned where we had located the fall and who represented himself as being one of my associates. The exact location of some of these falls has not been ascertained.

heavy and dark, and appears vitreous in the best preserved specimens. In most cases, the crust is beset with prominent ridges which appear to have resulted from the congealing of a viscid molten glass. Between the ridges and in some cases traversing them are numerous contraction cracks.

All of the stones were completely incrusted when found, excepting those which appear to have been broken by their impact with the soil. About 50% of them show definite orientation. In those which are oriented, the rear side is largely free from the ridges previously mentioned; it is covered by a rather smooth, tar-like glaze, which is more or less beset with gas bubbles and explosion pits. In some cases this rear crust is marked also by one or more concentrically developed terraces which have been formed by the overflowing of molten glass from the adjacent surfaces. In one instance the junction between the base and the lateral boundary of the stone is denticulated with pointed pyramids of black glass projecting rearward (see Fig. 3).

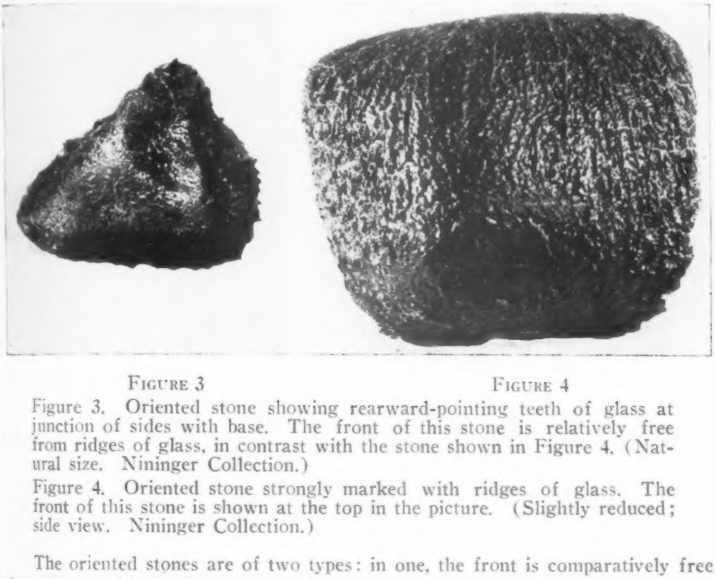

FIGURE 3 FIGURE 4

Figure 3. Oriented stone showing rearward-pointing teeth of glass at junction of sides with base. The front of this stone is relatively free from ridges of glass, in contrast with the stone shown in Figure 4. (Natural size. Nininger Collection.)

Figure 4. Oriented stone strongly marked with ridges of glass. The front of this stone is shown at the top in the picture. (Slightly reduced; side view. Nininger Collection.)

The oriented stones are of two types: in one, the front is comparatively free from ridges, while in the other the ridges are very prominent (see Figs. 1 and 3). With one exception all of the unoriented stones bear prominent ridges. This single exception is incrusted with a glossy layer of black glass and is slightly pitted—the only specimen which shows any pitting. This specimen shows a partially fused interior which is somewhat blackened in places to a depth of several millimeters below the true fusion crust. Its appearance first suggested artificial heating, but we have been unable to learn of any such treatment from the finder.

Distribution of the Stones

Nearly all of the stones found had been left as surface residue; however, in view of the heavy dust storms which have been so frequent in the region, it is possible that some of the stones which have been picked up on the surface were in reality soil intrusions which had been laid bare by the wind storms. There were cases where two 3-ounce stones were said to have been found half imbedded in the subsoil in fields from which the cultivated layer had been removed by blowing, subsequently to the date of fall. If these reports are true, these stones had buried themselves to a depth of about four inches in dry tilled soil, because we know that the blowing occurred after the meteorites fell. There is some uncertainty about these cases, however.

This fall established a new record as to the distance of separation between members of a single fall and also by the fact that all finds have been made back of the end point of the visible meteor. The nearest approach to the end point of the visible meteor was about 10 miles, and the various other fragments were scattered back along the trail from this point to a distance of 28 miles. In this statement we are using as the location for the end point that which can be relied upon as conservative. Some very good evidence has been submitted to indicate that the meteor continued farther before it disappeared. It is not improbable that it proceeded actually as far as 20 miles in a diminished form, beyond the point which has been designated in my survey as the end point; but we may be sure that the point designated in the survey is about correct for that place where the greater part of the light vanished. By the majority of the observers, no light was seen beyond this point. However, the meteor's brilliance was such as temporarily to produce a blinding effect, and it is probable that those persons who insist that the light carried farther were those whose eyes recovered from the effect of the dazzling brilliance more promptly than did the eyes of the other observers. In any case, the entire distribution of stones, as far as has been discovered, fell far short of the end point of the meteor. The only comparable case that I have been able to find on record is that of the Rochester, Indiana, stone. This stone is credited to the great procession of December 21, 1876, which proceeded, according to Kirkwood, about 200 miles after it passed Rochester, where the stone fell.

After I had spent weeks of time and several hundred dollars in an effort to complete a reasonably accurate survey of this important fall, it was gratifying to learn that the distribution of stones conformed to the line of flight which I had designated. The line which had been drawn on my map months before the first stone was reported, still remains where originally placed at its west end. It lies about four miles to the south of the meteorite-sprinkled area and almost parallel to it. This northerly displacement of the meteorites is what one would expect in view of the fact that a brisk wind blew from the south on the morning of March 24, 1933. Stones averaging one ounce each in weight would have drifted considerably to the north of their target in falling twenty miles. The explosion or explosions which set these stones free must have occurred above this height. At its eastern extremity, the meteorite field lies about five miles north of the designated line of flight. This extremity, being 25 miles farther back along the course of the meteor, where the elevation of the fireball was about one-seventh greater than at the end point, would allow for a correspondingly greater displacement of the falling fragments by air currents.

The large persistent cloud which the March 24, 1933, meteorite left in the stratosphere is regarded by the writer as the most significant aspect of this remarkable fall. Indeed it may be expected that when the scientific world becomes sufficiently aware of their magnitude and the nature of their production, meteoritic clouds will be regarded as among the most important of terrestrial phenomena. A few writers have emphasized to some extent the size of these clouds, but apparently in the minds of most scientists they are very insignificant. I have called attention to the size of this cloud in my previous paper;[4] but at that time there was some uncertainty in regard to its true nature, because the meteorite had not then been found. Now that the meteorite has been examined, it seems quite evident that the cloud was just what it appeared to be, namely, finely comminuted meteorite which escaped volatilization and liquefaction as it was discharged in flight. The meteorite consists of a tufaceous material much of which is so finely divided that, when a piece of the stone is broken or rubbed, it emits a cloud of dust so fine that it rises like smoke from a cigarette. This material is now believed to have been mainly responsible for the unusually large cloud which followed the meteor; in ordinary falls the resulting cloud is often only a few cubic miles in extent. Whether one or a thousand cubic miles in volume, a cloud in the stratosphere left by a meteor is an important phenomenon. Every available means should be brought to bear upon the significant questions which arise as to the nature and mass of these gigantic apparitions whose dimensions surpass those of nearly all other terrestrial objects which are viewed by man.

Recent discoveries by aërodynamical engineers throw much light on this aspect of the March 24, 1933, meteor and meteorite. These workers have found that atmospheric resistance, where high velocities are involved, is far greater than had been formerly supposed. At the speed of sound or thereabouts, instead of the atmospheric resistance varying as the square of the projectile's velocity, as had been considered the rule for ordinary vehicular rates of travel, they find that the resistance varies as the *sixth* power of the velocity! This astounding increase in the ratio between velocity and resistance can only weakly suggest what is probably the ratio at velocities such as characterize the flight of meteorites. The average meteorite enters the atmosphere traveling about 130 times as fast as sound. This number raised to the sixth power gives us the unthinkable figure of 4,826,809,000,000! The highest power steel-jacketed bullet leaves the muzzle of a gun with a speed about three times that of sound. The air resistance at this speed is sufficient to melt lead or to produce a temperature of perhaps 350° to 500° C. According to the preceding formula, the resistance offered to an invading meteorite should be about 4,000,000,000 times as great as that encountered by a bullet in a medium of the same density. The outermost zone of the atmosphere is of course very tenuous, but even so, it is evident that the conflict between meteorites and our atmosphere must be extremely violent. The March 24, 1933, meteorite encountered the earth in almost a direct head-on collision, with a relative velocity of about 40 miles per second. The resistance which it experienced was no doubt sufficient to keep its surface layers in a state of constant violent volatilization. In other words, there was a protracted explosion in progress all over the forward and lateral exposures of the meteorite. This process in a fair way represented the rocket idea except that in this instance the rocket was traveling at high speed and was being checked by the rocket-propelling principle acting in reverse. As the velocity was reduced, the volatilization gave place to liquefaction which was responsible for the glassy incrustation with which each fragment finished its course.

Throughout the burning flight there was much crumbling or crushing of the meteorite, and some of the débris thus produced escaped both fusion and volatilization and was driven outward to form the cloud of gray material which persisted in the stratosphere. This cloud no doubt rained minute particles over hundreds of square miles during the hours which succeeded the meteor's passage. Unfortunately, our survey was not finished promptly enough to verify this assump-

[4] *Loc. cit.*, pp. 295-8.

tion. Shortly after the meteor's passage, a strong wind from the south filled the air with dust and sand which would have caused any rain of meteoritic particles to be overlooked by the untrained residents.

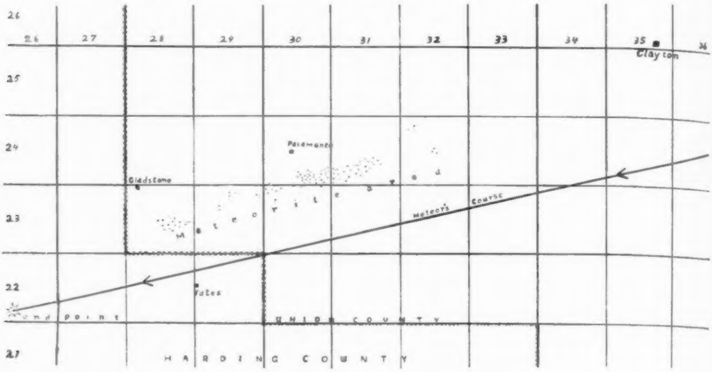

FIGURE 5

Township map of the southwestern part of Union County, New Mexico, showing the path of the March 24, 1933, meteor and (roughly) the distribution of the meteorites subsequently recovered near Pasamonte, *i.e.* the meteorite-sprinkled area. (Survey by the Nininger Laboratory.)

The accompanying map shows the distribution of the stones which were found. In general the larger stones were toward the western end of the area in Twp. 23 N, R 28 E.

The Fourth Annual Meeting

As announced in the May issue (p. 283), the Fourth Annual Meeting of the Society will be held at the University of California at Los Angeles on June 23 and 24, 1936. At the morning session on June 23, Dr. Arthur S. King, Superintendent of the Physical Laboratory of the Mount Wilson Observatory, Pasadena, by invitation will read a paper (illustrated) on "The Spectra of Meteorites," and at the afternoon session on the same day, Dr. Mars F. Baumgardt of Los Angeles, also by invitation, will deliver a semi-popular illustrated lecture on "The Meteorite Crater of Arizona." All the scientific sessions of the meeting will be open to the public.

Secretary's Office: Nininger Laboratory, 1955 Fairfax Street, Denver Colorado.
Editorial Office: Department of Astronomy, University of California at Los Angeles.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Observers and Observations: Two new observers appear in the list of contributors for April, Mr. Hideo Inouye, of Nagoya, Japan, and Mr. A. Thomas Murphy, of San Francisco, California. In spite of the inclement weather reported